RESEARCH ARTICLE

Preparation and Evaluation of Polypropylene-Peanut Shell Flour Eco-Friendly Composites with and without Cloisite 30B

Haydar U. Zaman*[1], Ruhul A. Khan[2]

[1]National University of Bangladesh and Senior Researcher of Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh

[2]Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh

ABSTRACT: Polymer composites strengthened with natural fibers are much attractive than traditional component due to their availability, renewability, low weight and cost, low density, and biodegradability. There are a variety of natural fibers, such as coir, hemp, jute, and palm that can be applied as reinforcement or filler, showing potential as a replacement for inorganic fibers. Plastics are frequently somewhat cost-effective when making complex shapes, and the likelihood of obtaining composite ingredients with short demolding times, as no chemical reactions are required, makes them very attractive from an industrial standpoint. In this regard, the objective of this work was to prepare composites of polypropylene (PP) with two types of compatibilizers (maleated PP, PPM or maleated styrene ethylene-co-butylene styrene block copolymer, SEBSM) with varying amounts of 1, 3, and 5 wt% and different amounts of nanoclay, Cloisite 30B (1, 3, and 5 wt%) with peanut shell flour (PSF, 50 wt%) and evaluated the effect on mechanical properties, morphological, and dimensional stability. The addition of PSF to PPM increased the tensile strength and impact strength of the composite but the tensile modulus remained essentially unchanged. On the other hand, SEBSM had a large effect on impact strength but reduced modulus in addition to a small effect on tensile strength. Addition of both compatibilizers increased the impact strength, but did not decrease the tensile strength. Incorporation of cloisite 30B increases tensile modulus without reducing impact strength, the use of all three additives offers the possibility to produce natural fiber-plastic composites with high modulus and high impact strength.

KEYWORDS: Nanocomposite, cloisite 30B, peanut shell flour, polypropylene, coupling agents, mechanical properties

https://doi.org/10.29294/IJASE.9.2.2022.2658-2668 **©2022 Mahendrapublications.com, All rights reserved**

INTRODUCTION

To reduce ecological contamination from synthetic filler-based composites, scientists are now attention to renewable resources and agricultural waste for the improvement of natural fiber (NF)-based composites, also recognized as fiber-reinforced composites. This kind of biocomposites is gaining more interest in the development and in recent research. NFs are usually categorized into several of types depending on their source. Animal fibers, such as hair and silk and mineral fibers were not widely used as strengthening fibers. Natural plant fibers include a variety of fibers such as bast (flax, hemp, jute, kenaf, ramie), seed (coir, cotton, kapok), straw (corn, rice, wheat), grass (bamboo, bagasse), leaf (abaca, banana, curaua, henequen, pineapple, sisal), and wood fibers (softwood, hardwood). The main chemical composition of plant fibers is lignocellulose (cellulose, hemicellulose, and lignin) and the amount of these elements depends on the type of fiber [1-3]. NFs can significantly strengthen thermoplastics and thermosetting. Deforestation has resulted in the use of rice husk, cotton, jute, bagasse, straw, cobs, sisal, banana, alpha, coir, bamboo, almond husk, etc. as an alternative to timber in countries without timber resources. PP is one of the most common thermoplastic polymers for making NF reinforced composites due to its low cost, low density, good mechanical features and comfort of handling. The composites made by mixing these fibers with virgin synthetic polymers can be used in building construction, automobile industry, packaging, and furniture due to environmental and ecological concerns. NFs can be used as substitute fillers for clay, carbon-, glass-and aramid fibers, and therefore evading

**Corresponding Author: haydarsaman07@gmail.com*

Received: 10.09.2022 **Accepted:** 17.10.2022 **Published on**: 01.11.2022

toxic by-products during the industrial procedure [4-6]. The benefits of NFs are low density, good strength features, and wide availability, low cost, less tool wear, renewability, and easy fiber surface modification, absence of associated health hazards, relative nonabrasiveness and good biodegradability. While the combination of untreated NF with synthetic polymers has several merits, since NF is hydrophilic nature, it, therefore, limits the compatibility of NF with hydrophobic synthetic polymers. Poor bonding between the two components [7] due to inadequate dispersion and poor interfacial adhesion [8] may lead to poor performance of the final product of different chemical nature, hence less mechanical properties [9]. The main tool to overcome this problem is to improve the mutual adhesion and this can be achieved by modifying the surface of the fibers or using adhesive promoters [10]. Modification through compatibilizers or coupling agents can introduce new functional groups into the NF that are capable of forming chemical bonds between the cellulose chain and the synthetic polymer matrix [11-14]. The compatibilizer performs as a connection between the fiber and the polymer matrix. Compatibilizer such as maleated polypropylene (PPM) is widely used for their effectiveness in fiber–polymer composites. The polypropylene (PP) chain of PPM spreads to the PP of the matrix resulting in better adhesion or entanglement. This procedure develops the interfacial bond between the fiber and the polymer matrix [15]. SEBSM has been used as a compatibilizer and toughening agent for polymer blends containing glass fibers [16]. Especially, it is compatible with PP, PE, and PS because it has different components that make it compatible with these different polymers. Consequently, it is reasonable to use SEBSM as a coupling agent in PP-based composites. Oksman et al. considered the effects of adding SEBS-g-MA to the features of PP or PE-based wood-plastic composites [17].

Among the various NFs, PSF is of specific interest. The peanut (*Arachis hypogaea*) is one of the most important food crops grown in countries with subtropical climates and a valuable foodstuff used all over the world. Peanut production produces a large amount of waste called peanut shells. Peanuts are edible but their shells are waste; they are often called groundnuts because their pods (shells) grow under the ground. Peanut shell is a plentiful agro-industrial waste product that leads to massive savings around the world, however, it is a renewable resource that can be used in food, feed, paper, and bioenergy, and if any value-added use exists [18]. The application of lignocellulosic fillers present in the peanut shell is of great interest, possessing unique properties, such as being less abrasive in tooling and not having workers' respiratory problems [19]. After separating the peanut from the shell or hull the shells are discarded. The peanut shell is a lignocellulosic component that is a complex fibrous structure composed of cellulose (44.8%), hemicellulose (5.6%), and lignin (36.1%) [20].

Over the past decade, several researchers have informed that including organoclays at very low loading (< 5 wt%) in polymers can dramatically develop mechanical, thermal, and processing properties [21]. Improvements in these properties are achieved through a good dispersion of the polymer clay to form an intercalated or exfoliated nanostructure [22]. It was also found that PPM acts as a dispersant and is compatible to increase the melt intercalation of PP in the galleries of clay platelets [23]. In low-polarity polymers, such as PP, low compatibility between polymers and clays is observed during mixing which leads to poor dispersion [24]. The use of PPM as a compatibilizer improves the dimensional stability and mechanical properties of PP, PSF, and nanoclay composites by improving the adhesion between PP-PSF as well as enhancing the interaction between PP-organoclays. Nevertheless, the minute effort has been made to increase the features of PP/PSF composites, including nanoclay. Incorporating peanut shell flour can effectively reduce production costs by fully or partially replacing other expensive fillers, therefore presenting an agricultural residue as a useful industrial resource, adding positively to the environment. The objectives are: (1) to prepare PP/PSF composites containing exfoliated nanoclay and (2) to study the effect of clay on the mechanical properties, as well as the physical properties of PP/PSF composites.

EXPERIMENTAL

Materials

The polymer used to make the composite was virgin polypropylene (PP) in the form of pellets. The melt flow index (MFI) of PP was 5–7 g/10

min (at 230°C/2.16 kg), and their density was 0.9 g/cm^3. Peanut shells, collected from a local mill, were used as the raw material. Nanoclay (organically modified montmorillonites, Cloisite 30B) was supplied by Southern Clay Products Inc., USA. Cloisite 30B is an alkyl quaternary ammonium salt bentonite additive for plastics and rubber that can improve various physical properties such as reinforcement. Maleated polypropylene (PPM, Fusabond® P MZ 109D, DuPont) was supplied by Chemical Innovation Co., Ltd. SEBSM was supplied by Kraton, it is a linear triblock copolymer based on styrene and ethylene/butylene, with a polystyrene content of 30% and maleic anhydride content of 2 wt%. An antioxidant at 0.1 wt% level was used to prevent the degradation of the polymer during melt compounding. It is a mixture of phenol and phosphate, and it was distributed by Chemtura.

METHODS

Preparation of Peanut shell Flour

The peanut shells were washed with water and dried in the natural sun for two days. The dried peanut shells were crushed in a pulverized machine, which yielded an average particle diameter of approximately 68.5 μm. PSF was then dried for 2 h at 70°C using a vacuum oven before being used for composite fabrication.

Composite Preparation and Processing

Before compounding, PPM or SEBSM pellets were hand-mixed with PP pellets in a bag before loading into the feeder. PSF was pre-dried in an oven at 100°C for 24 h with a moisture content of less than 1 wt%, while the nanoclay was pre-dried at 80°C for 24 h. Nanocomposite samples were prepared with different amounts of nanoclay (1, 3, and 5 wt%), the preweighed quantity of PP with two types of compatibilizers (PPM or SEBSM) with varying amounts of 1, 3, and 5 wt% as follows. Compositions of sorted nanocomposites are recorded in Table 1.

Table 1 Composition of various PP/PSF composites

PP (wt%)	PPM (wt%)	SEBSM (wt%)	Nanoclay (wt%)	PSF (wt%)
50	n/a	n/a	n/a	50
49	1	n/a	n/a	50
47	3	n/a	n/a	50
45	5	n/a	n/a	50
49	n/a	1	n/a	50
47	n/a	3	n/a	50
45	n/a	5	n/a	50
46	3	1	n/a	50
44	3	3	n/a	50
42	3	5	n/a	50
45	3	1	1	50
43	3	1	3	50
41	3	1	5	50

There are two methods involved in making nanocomposites. These are twin-screw extrusion for compounding and injection molding for the mixing process. The melt blending was performed with a co-rotating twin-screw extruder (Brabender Plasticorder, model: PLE-331). Screw speed and temperature profiles were set at 50 rpm and 170, 180, 200, and 190°C, respectively. First, the PP was fed into the mixing chamber, and, after PP melted, a compatibilizer and nanoclay were added. After five minutes, the modified and unmodified PSFs were fed and the total mixing time was 10 min. The compounds were allowed to cool at room temperature and pelletized using a granular grinder (Wieser, WGLS 200/200 model). The grains were fitted with a standard ASTM mold using an injection molding (Toyo, model: Si180iiiE200, Japan) in the samples to test the tensile and impact properties at a temperature of 190°C. Lastly, as stated by ASTM D618-99 before testing, the specimens were conditioned at a temperature of 25°C and 55% relative humidity for at least 24 h.

CHARACTERIZATION

Mechanical Testing

Tensile properties such as tensile strength, tensile modulus, and elongation at break of composite samples were measured at a crosshead speed of 5 mm/min using a universal testing machine (model 4486) according to the

ASTM D-638 test method. A Tinius Olsen T-92 impact tester (testing machine, PA, USA) was used to test the Izod impact strength. Typically wood-plastic composites showed relatively low impact strength in standard Izod impact tests, the reverse notch impact test method was applied. All specimens were notched at a longitudinal center point according to ASTM test D 256-0620. At least five samples were tested for each composition and average values were reported.

Morphological Studies

The fracture surfaces of the tensile test specimens were investigated using a scanning electron microscope (SEM; JEOL, Japan JSM-6360LV) at an accelerating voltage of 15 kV. The fracture surfaces of the specimens were covered with a small layer (10–20 nm) to protect the gold.

Dimensional Stability Assessments

Water absorption (WA) and thickness swelling (TS) assessments were shown by ASTM D-570. Before the test, the weight and dimensions of each sample, i.e. length, width, and thickness, were examined. Conditional samples were soaked in distilled water at 25°C for 5 and 24 h. At the end of the predetermined period, the samples were withdrawn from the water; all surfaces were wiped off with a cloth and then weighed. After 5 h of soaking, the samples were replaced in water and weighed again after 24 h. Water absorption was calculated according to the following equation.

$$WA(\%)=[(W_b-W_a)/W_a]\times 100 \quad (1)$$

where WA is the water absorption in percentage and W_a, and W_b are the sample weights before and after soaking (g). The values of the TS in percentage were calculated using the following equation.

$$TS(\%) = [(T_w-T_i)/T_i] \times 100 \quad (2)$$

Where, T_w is the thickness of the wetted sample and T_i is the initial thickness of the sample.

RESULTS AND DISCUSSION

Mechanical Properties of the Composites

The tensile strength and tensile modulus of the PP/PSF composite containing dissimilar quantities of PPM or SEBSM are presented in Figures 1(a) and 1(b), respectively. As can be seen in Figure 1(a), the tensile strength of the PP/PSF composite increased from 27.3 MPa to 40.6 MPa while the PPM loading level increased from 0 wt% to 3 wt%. Nevertheless, there were deteriorating returns on adding PPM beyond the 3 wt%. For instance, when the loading level of PPM was increased from 3 wt% to 5 wt%, the tensile strength increased by a further 6.9 MPa. Therefore, adding 3 wt% of PPM to PP/PSF composites appears to be the optimal loading level of the coupling agent required to offer good adhesion between PP and PSF. Figure 1(a) displays the effect of the PPM coupling agent on the tensile modulus of the PP/PSF composite. It was perceived that the tensile modulus improved to a maximum value around a coupling agent content of 3.0 wt % of PSFs. After that, the tensile modulus tends to be stable. Optimal concentration (approximately 3.0 wt% PPM), providing maximum tensile modulus and tensile strength in composites, indicates high interfacial interactions between PSF and PP matrix. It was added with the ester linkages formed by the chemical reaction of PPM coupling agents and peanut shell particles, and the physical entanglement of PP molecules from PPM coupling agents, and a description of this process can be found elsewhere [25]. On the other hand, we see from Figure 1(b) that when 1 wt% of SEBSM was added to the composite, the tensile strength and tensile modulus of PP/PSF composites first increased and then decreased with the SEBSM loading level. This is not astonishing because it is recognized that when elastomers are used as impact modifiers in thermoplastics, tensile strength and tensile modulus drop [26]. SEBSM is an elastomer and does not transfer as much stress to the strain obtained for maximum stress transfer, and, therefore, these properties are lower than PPM

The elongation at break of PP/PSF composite with the additional amount of the two coupling agents is displayed in Figure 2(a). It is expected that the elongation at break of PP/PSF composites containing SEBSM is first increased to 1 wt% loading level and then leveled off to a higher loading level. The elongation at break with PPM loading levels also increases, especially when PPM content exceeds 1 wt%. It should be noted that the elongation at break of PP/PSF composites does not increase at low PPM content. The cause of these requirements is to be more investigated. Figure 2(b) illustrates the impact strength of PP/PSF

composite with different amounts of added PPM or SEBSM coupling agent. It has been found that both PPM and SEBSM increase the reverse-notch impact strength, but SEBSM offers better impact resistance than PPM. In the case of SEBSM, 1 wt% addition gives more than a 151% increase in impact strength, whereas, in PPM, 3 wt% of PPM gives an optimal improvement in impact strength. The effect of combining the two coupling agents was subsequently studied.

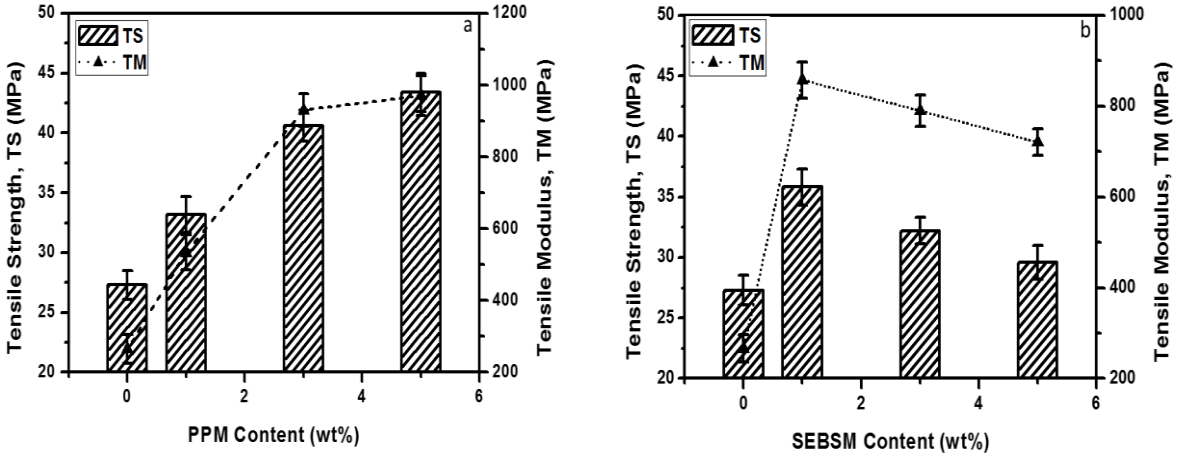

Figure 1 Tensile strength and tensile modulus of PP/PSF composites formulated with (a) PPM and (b) SEBSM

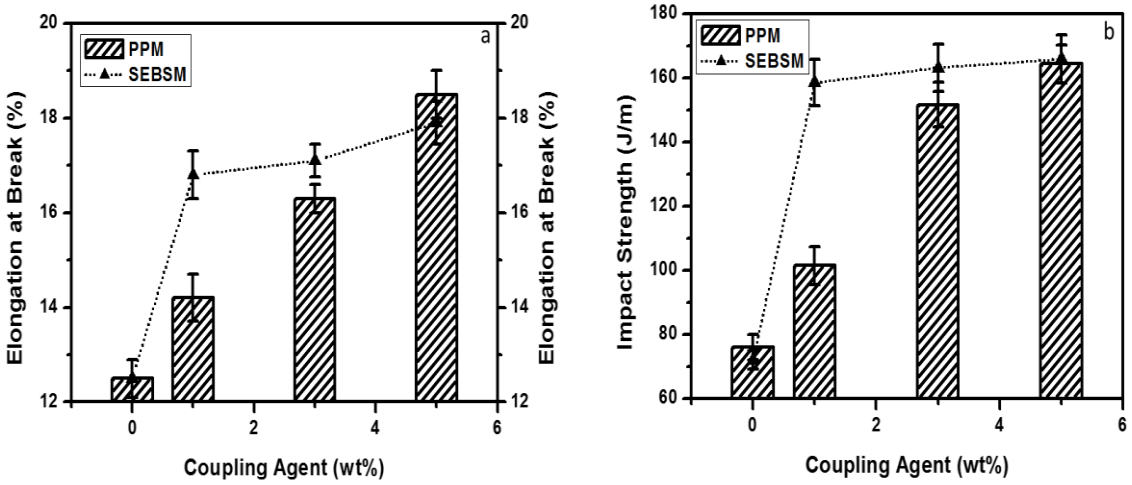

Figure 2 (a) Elongation at break (%) and (b) reverse-notch impact strength (J/m) of PP/PSF composites formulated with PPM or SEBSM

Subsequently, 3 wt% of PPM provided good tensile and impact strength, the loading level of PPM was fixed at 3 wt%, and the SEBSM content was varied. The tensile strength and tensile modulus of the PP/PSF composite have different amounts of SEBSM and a certain amount of 3 wt% PPM as shown in Figure 3(a). It has been observed that in the presence of SEBSM both tensile strength and tensile modulus are reduced. Property reduction, however, is not large. With the addition of 1 wt% of SEBSM, the tensile strength decreased by only 10.5%, while the tensile modulus decreased by only 6.8%. The reverse-notch Izod impact strength and elongation at break of these same PP/PSF composites are presented in Figure 3(b). Adding only 1 wt% of SEBSM the reverse-notch Izod impact strength increased from 151.6 J/m to 191.3 J/m (26.2%), while the elongation at break increased from 17.5% to almost 20.4% (16.5%). For comparison, it should be noted that the reverse-notch Izod impact strength of PP/PSF composites without additive is 76.1 J/m. In the presence of 3 wt% of PPM, this value increases to 151.6 J/m, and when added 1 wt% of SEBSM to the composite, it increases further to 191.3 J/m. It can now be said that the reverse-notch Izod impact strength of the PP/PSF composite improved 2.8 times when only 3 wt% of the combination of the two coupling agents was added. When SEBSM was added to the PP/PSF composite, a covalent

reaction occurred between the maleic anhydride group of SEBSM and the hydroxyl groups of PSF to form the SEBS-OH (fiber) copolymer [27].

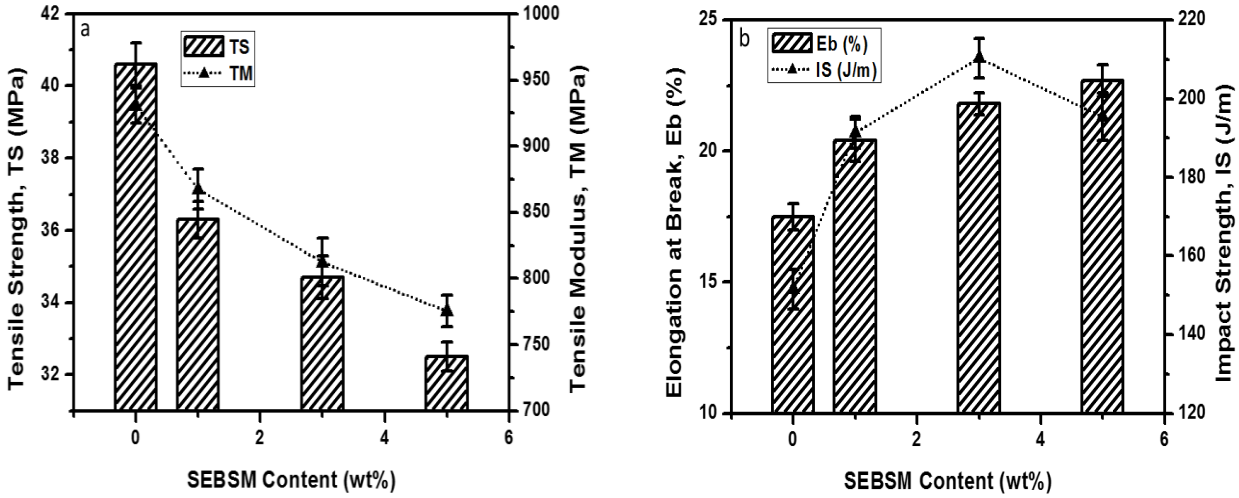

Figure 3 (a) Tensile strength and tensile modulus (b) elongation at break (%) and reverse-notch impact strength (J/m) of PP/PSF composites containing 3wt% of PPM and different amounts of SEBSM

Adding just 1 wt% of SEBSM can significantly increase both the elongation at break and the impact strength of PP/PSF composites without reducing the tensile modulus, just to see if adding 1 wt% of SEBSM to PP/PSF composites reinforced with nanoclay would improve the impact strength. These outcomes are presented in Figures 4-5 for the mechanical features of PP/PSF composites containing nanoclay. As can be seen from Figures 4(a) and 4(b), adding 1 wt% of SEBSM does not affect the tensile strength or tensile modulus of PP/PSF composites. These outcomes are consistent with the corresponding results for PP/PSF composites without nanoclay. Also, as shown in Figure 5(a), 1 wt% of SEBSM helps to increase the elongation at break of the PP/PSF composite slightly but not significantly. On the other hand, Figure 5(b) displays that adding 1 wt% of SEBSM increases the reverse-notch Izod impact strength of PP/PSF composites. Therefore, a small amount of SEBSM can significantly improve the impact strength of PP/PSF composites without adversely affecting other mechanical properties.

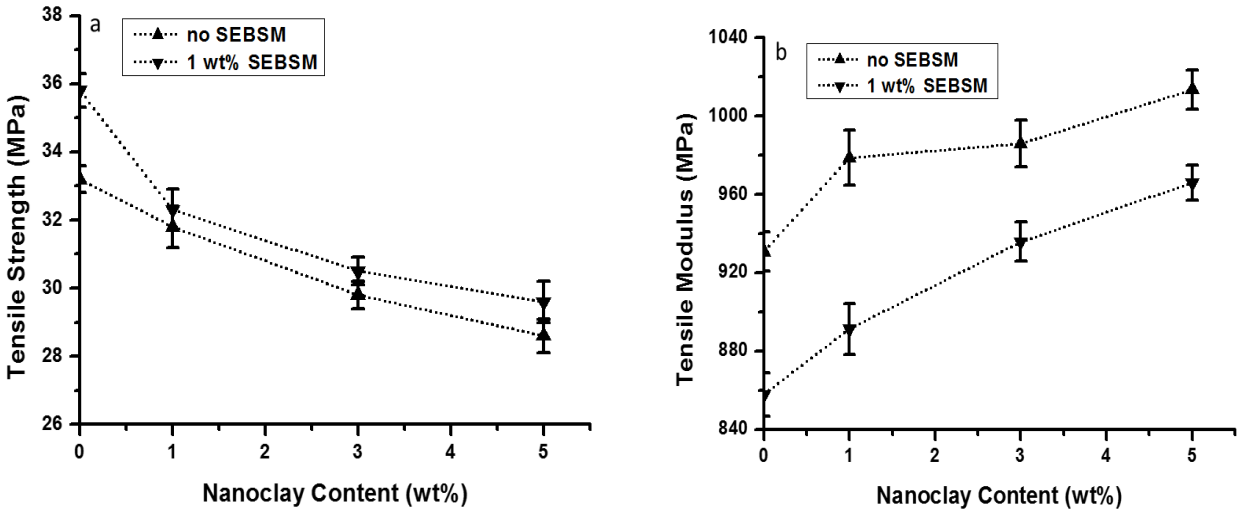

Figure 4 (a) Tensile strength and (b) tensile modulus of PP/PSF composites reinforced with nanoclay in the presence and absence of 1 wt% of SEBSM

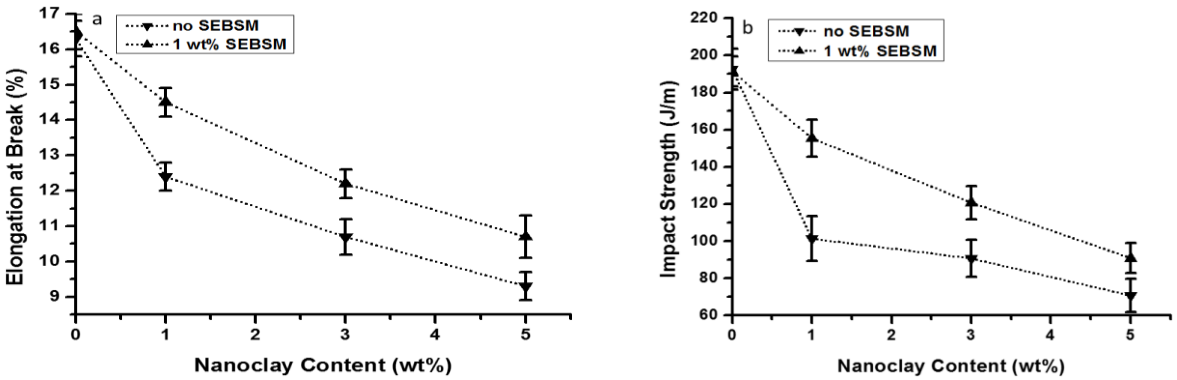

Figure 5 (a) Elongation at break (%) and (b) reverse-notch impact strength (J/m) of PP/PSF composites reinforced with nanoclay in the presence and absence of 1 wt% of SEBSM

Surface Morphology Observation

SEM is an analytical device that has proven to be extremely significant for the exploration of filler structures. SEM offers a great strategy for studying the surface morphology of unmodified and chemically modified PSFs. Figure 6(a) shows that the micrograph of the uncompatibilized PP/PSF composite sample (50/50 wt%) was stiff, compact, and disorganized. It can be observed from Figure 6(a) that the filler was embedded in the matrix and arranged in a distorted method and that most PSFs were in direct contact with other PSF particles. Some fillers have been removed or left loose in the PP matrix. Moreover, Figure 6(a) shows the weak adherence of the filler to the PP matrix, as is evident from the void between the matrix and the filler particle. These voids act as points of stress concentration and contribute to the reduction of mechanical properties and there is a higher rate of water absorption. Figure 6(b) shows the SEM micrograph of the compatibilized PP/PSF composites with 3 wt% PPM + 1 wt% SEBSM loading. From the outcomes, it was perceived that the gaps and crack lines are not as clear as observed in the sample combined with the inconsistent PSF. The gaps were thin and much smaller. Clearly, from Figure 6(b), less is drawn from the filler, and filler agglomeration can be observed. These are related to the inclusion of compatibilizers, which improve filler adhesion to the matrix. Furthermore, a higher toughening effect can be observed compared to uncompatibilized composites [28]. These results are evidence of good interfacial adhesion between the filler and the matrix, as a result of the esterification mechanism with the addition of the coupling agent [29], which leads to improved tensile strength, tensile modulus, and elongation at break. It further exhibits that PPM/SEBSM is an effective compatibilizer for these composites. Figure 6(c) presents the effect of nanoclay addition in PP/3 wt% PPM + 1 wt% SEBSM composite samples. The addition of nanoclay content (3 wt%) exhibits uniform dispersion of nanoclay layers in the polymer matrix, leaving a relatively smooth fractured surface. This ensured that most of the dispersed nanoclay particles filled the gaps in the interface between PP and PSF, which improved the interface adhesion of the composite components. Such SEM observations have established the exfoliated and intercalated structures of nanoclay that were formed within the composites. From the SEM analysis, it was concluded that the inclusion of PPM or SEBSM and nanoclays improved the interfacial adherence between PP matrix and PSF. The mechanical features discussed earlier also confirmed this outcome.

The Study of Physical Features

Water Absorption

Table 2 exhibits the water absorption percentage of PP/PSF, PP/3 wt% PPM + 1 wt% SEBSM/PSF, and PP/3 wt% PPM + 1 wt% SEBSM/PSF/nanoclay nanocomposites ay various nanoclay contents after 5 and 24 h water soaking times. Increasing water absorption capacity of the material was observed to increase with increasing soaking time. Water intake is one of the main parameters for evaluating the quality of composites. Although the water absorption of virgin PP was so low (0.021 and 0.052% after soaking in water for 5 and 24 hours, respectively) because PP is hydrophobic, with

the addition of PSF to formulations, water absorption increased.

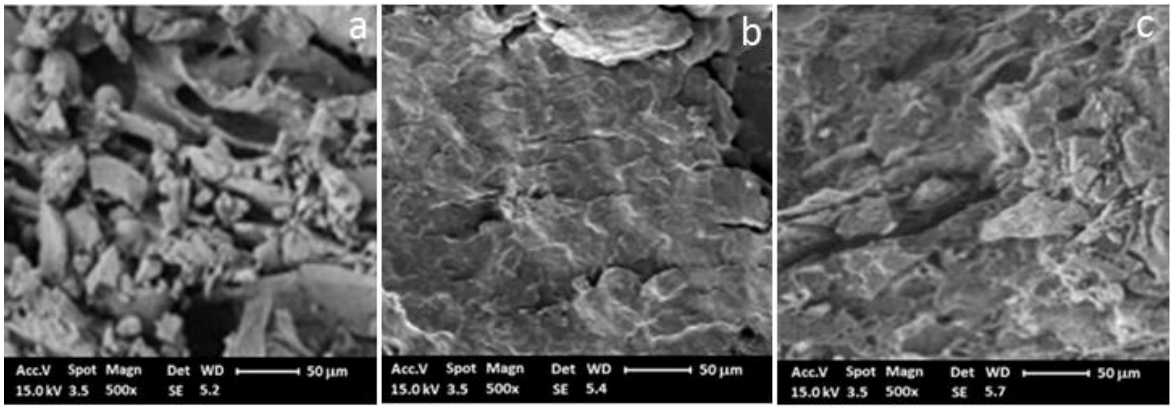
a
Acc.V Spot Magn Det WD 50 µm
15.0 kV 3.5 500x SE 5.2
b
Acc.V Spot Magn Det WD 50 µm
15.0 kV 3.5 500x SE 5.4
c
Acc.V Spot Magn Det WD 50 µm
15.0 kV 3.5 500x SE 5.7

Figure 6 SEM image of the tensile fracture surface of the (a) PP/PSF (50/50 wt% by fiber); (b) PP/3 wt% PPM + 1 wt% SEBSM/PSF; (c) PP/3 wt% PPM + 1 wt% SEBSM/3 wt% nanoclay/PSF composites

The hydrophilic nature of PSF (high contents of -OH groups in cellulose and hemicelluloses) was accountable for this [30]. The inclusion of PPM/SEBSM decreases the water absorption capacity, thereby improving the water-resistance features of the ingredient and widening the potential fields of application of the ingredient. The inclusion of PPM/SEBSM has improved surface adhesion between PSF and PP resulting in reduced water absorption. Water absorption of PP/PPM+SEBSM/PSF composites decreased with the inclusion of nanoclay. Adding nanoclay from 1 to 3 wt% increased water intake even though it was marginal. However, an increase in nanoclay content at 5 wt% to reduce water absorption capacity has been observed, but not as in the case of PPM/SEBSM. The higher the amount of clay leads to less water intake. Nanoclay increases the difficult path for water transport and, as an outcome, the diffusivity of water reduces [31]. Reducing the space available for water absorption due to the occupation of voice space in PSF by polymers and nanoclays may be another mechanism for low water uptake of nanocomposites [32]. The existence of nanoclay in the composite prevents the entry of water through the composite. The surface of the modified clay tended to immobilize some moisture [33]. The strong interfacial adhesion between the PSF and PP matrix caused by the compatibilizer and nanoclay reduces the water absorption of the composites. The composite with 5 wt% compatibilizer shows the lowest water absorption of all composites.

Thickness Swelling (TS)

The effect of nanoclay content on the TS of the composite is given in Table 2. As it turns out, TS decreases significantly with nanoclay inclusions. The higher the nanoclay content, the lower the TS. The TS of virgin PP is almost negligible, for example, 0.05% and 0.11% after soaking in water for 5 and 24 hours. The reasons for the improvement of TS with nanoclay loading are similar to the water absorption that was discussed earlier. This outcome is reliable to Valente et al [34].

Table 2 Water absorption and thickness swelling of the formulation studied

Sample code	Water absorption (%)		Thickness swelling (%)	
	5 h	24 h	5 h	24 h
VPP	0.021	0.052	0.056	0.153
PP/PSF	0.853	1.756	1.877	2.474
PP/A	0.356	1.259	1.380	2.250
PP/A/1NC	0.534	1.437	1.071	1.494
PP/A/3NC	0.493	1.396	1.03	1.339
PP/A/5NC	0.385	1.288	0.844	1.261

VPP: virgin PP; A: PPM + SEBSM; NC: nanoclay

CONCLUSION

Using extrusion and injection molding, a composite material based on PP filled with peanut shell flour (PSF) was manufactured. The effect of compatibilizers (PPM or SEBSM) and nanoclay (Cloisite 30B) content on the properties of the prepared PP/PSF composites was investigated. The morphology, mechanical properties as well as physical properties of PP/PPM or SEBSM/nanoclay nanocomposites were examined. It has been observed that the addition of PPM to PSF increased tensile strength and reverse-notch impact strength but the tensile modulus remained largely unchanged. In contrast, SEBSM had a larger effect on impact strength but in addition to a smaller effect on tensile strength; modulus was reduced. When adding both PPM and SEBSM to the PP/PSF composite, the impact strength increased by a factor greater than 2.8, but the tensile strength did not decrease. After adding 3 wt% of nanoclay to the composite formulation, experimental results indicate that (1) interface adhesion was improved (2) tensile strength, elongation at break, and impact strength were increased by 3.5%, 14%, and 71%, respectively (3) after 24 hours of immersion, the water absorption capacity decreased by 28.3%. However, adding more nanoclay did not improve these properties. This was attributed to further agglomeration and poor dispersion when using large amounts of clay, resulting in increased voids and cracks in PP/PSF composites. Presently, natural fiber polymer composites are a good alternative to the use of attractive and demanding materials and glass or carbon fiber and inorganic fillers to replace conventional materials to solve important environmental problems.

REFERENCES

[1] Sathishkumar, T., Navaneethakrishnan, P., Shankar, S., Rajasekar, R., Rajini, N., 2013. Characterization of natural fiber and composites-A review, Journal of Reinforced Plastics and Composites. 32, 1457-1476.

[2] Thakur, V.K., Thakur, M.K., Gupta, R.K., 2014. Raw natural fiber–based polymer composites, International Journal of Polymer Analysis and Characterization. 19, 256-271.

[3] Ramamoorthy, S.K., Skrifvars, M., Persson, A., 2015. A review of natural fibers used in biocomposites: Plant, animal and regenerated cellulose fibers, Polymer Reviews. 55, 107-162.

[4] Zaman, H.U., Khan, R.A., 2020. Surface Modification of Plant-Drive Calotropis Gigantea Fiber Reinforced Polypropylene Composites, Progress in Applied Science and Technology. 12, 23-35.

[5] Zaman, H.U., Khan, R.A., 2022. Surface Modified Benzoylated Okra (Abelmoschus esculentus) Bast Fiber Reinforced Polypropylene Composites, Advanced Journal of Science and Engineering. 3, 7-17.

[6] Zaman, H.U., Khan, R.A., Chowdhury, A., 2021. The improvement of physicomechanical, flame retardant, and thermal properties of lignocellulosic material filled polymer composites, Journal of Thermoplastic Composite Materials, 08927057211048535.

[7] Prabhakar, M., Shah, A.U.R., Rao, K.C., Song, J.-I., 2015. Mechanical and thermal properties of epoxy composites reinforced with waste peanut shell powder as a bio-filler, Fibers and Polymers. 16, 1119-1124.

[8] Kazayawoko, M., Balatinecz, J., Matuana, L., 1999. Surface modification and adhesion mechanisms in woodfiber-polypropylene composites, Journal of Materials Science. 34, 6189-6199.

[9] Rosa, S.M., Nachtigall, S., Ferreira, C.A., 2009. Thermal and dynamic-mechanical characterization of rice-husk filled polypropylene composites, Macromolecular Research. 17, 8-13.

[10] Zaaba, N.F., Ismail, H., Jaafar, M., 2014. The effects of modifying peanut shell powder with polyvinyl alcohol on the properties of recycled polypropylene and peanut shell powder composites, BioResources. 9, 2128-2142.

[11] Zaman, H.U., Khan, R.A., 2021. Acetylation used for natural fiber/polymer composites, Journal of Thermoplastic Composite Materials. 34, 3-23.

[12] Zaman, H.U., Beg, M., 2014. Effect of coir fiber content and compatibilizer on the properties of unidirectional coir fiber/polypropylene composites, Fibers and Polymers. 15, 831-838.

[13] Lai, S.M., Yeh, F.C., Wang, Y., Chan, H.C., Shen, H.F., 2003. Comparative study of maleated polyolefins as compatibilizers

for polyethylene/wood flour composites, Journal of Applied Polymer Science. 87, 487-496.

[14] Maldas, D., Kokta, B., 1994. Role of coupling agents on the performance of woodflour-filled polypropylene composites, International Journal of Polymeric Materials. 27, 77-88.

[15] Beckermann, G.: Performance of hemp-fibre reinforced polypropylene composite materials. The University of Waikato, 2007.

[16] Huang, J., Keskkula, H., Paul, D., 2006. Comparison of the toughening behavior of nylon 6 versus an amorphous polyamide using various maleated elastomers, Polymer. 47, 639-651.

[17] Oksman, K., Lindberg, H., 1998. Influence of thermoplastic elastomers on adhesion in polyethylene–wood flour composites, Journal of Applied Polymer Science. 68, 1845-1855.

[18] Wilson, K., Yang, H., Seo, C.W., Marshall, W.E., 2006. Select metal adsorption by activated carbon made from peanut shells, Bioresource technology. 97, 2266-2270.

[19] Mohanty, A., Misra, M.a., Hinrichsen, G., 2000. Biofibres, biodegradable polymers and biocomposites: An overview, Macromolecular materials and Engineering. 276, 1-24.

[20] Rubin, E.M., 2008. Genomics of cellulosic biofuels, Nature. 454, 841-845.

[21] Biswal, M., Mohanty, S., Nayak, S.K., 2009. Influence of organically modified nanoclay on the performance of pineapple leaf fiber-reinforced polypropylene nanocomposites, Journal of Applied Polymer Science. 114, 4091-4103.

[22] Rodríguez-Llamazares, S., Rivas, B.L., Pérez, M., Perrin-Sarazin, F., Maldonado, A., Venegas, C., 2011. The effect of clay type and of clay-masterbatch product in the preparation of polypropylene/clay nanocomposites, Journal of Applied Polymer Science. 122, 2013-2025.

[23] Yeh, S.K., Gupta, R.K., 2010. Nanoclay-reinforced, polypropylene-based wood–plastic composites, Polymer Engineering & Science. 50, 2013-2020.

[24] Ferreira, J., Reis, P., Costa, J., Richardson, B., Richardson, M., 2011. A study of the mechanical properties on polypropylene enhanced by surface treated nanoclays, Composites Part B: Engineering. 42, 1366-1372.

[25] Li, Q., Matuana, L.M., 2003. Surface of cellulosic materials modified with functionalized polyethylene coupling agents, Journal of Applied Polymer Science. 88, 278-286.

[26] Oksman, K., Clemons, C., 1998. Mechanical properties and morphology of impact modified polypropylene-wood flour composites, Journal of Applied Polymer Science. 67, 1503-1513.

[27] Ishak, Z.M., Chow, W., Takeichi, T., 2008. Influence of SEBS-g-MA on morphology, mechanical, and thermal properties of PA6/PP/organoclay nanocomposites, European Polymer Journal. 44, 1023-1039.

[28] Cao, X.V., Ismail, H., Rashid, A.A., Takeichi, T., Vo-Huu, T., 2011. Mechanical properties and water absorption of kenaf powder filled recycled high density polyethylene/natural rubber biocomposites using MAPE as a compatibilizer, BioResources. 6, 3260-3271.

[29] Catto, A.L., Stefani, B.V., Ribeiro, V.F., Santana, R.M.C., 2014. Influence of coupling agent in compatibility of post-consumer HDPE in thermoplastic composites reinforced with eucalyptus fiber, Materials Research. 17, 203-209.

[30] Nourbakhsh, A., Baghlani, F.F., Ashori, A., 2011. Nano-SiO2 filled rice husk/polypropylene composites: Physico-mechanical properties, Industrial Crops and Products. 33, 183-187.

[31] Alexandre, B., Marais, S., Langevin, D., Médéric, P., Aubry, T., 2006. Nanocomposite-based polyamide 12/montmorillonite: relationships between structures and transport properties, Desalination. 199, 164-166.

[32] Deka, B.K., Maji, T., 2010. Effect of coupling agent and nanoclay on properties of HDPE, LDPE, PP, PVC blend and Phargamites karka nanocomposite, Composites Science and Technology. 70, 1755-1761.

[33] Lee, H., Kim, D.S., 2009. Preparation and physical properties of wood/polypropylene/clay nanocomposites, Journal of Applied Polymer Science. 111, 2769-2776.

[34] Valente, M., Sarasini, F., Marra, F., Tirillò, J., Pulci, G., 2011. Hybrid recycled glass

fiber/wood flour thermoplastic composites: Manufacturing and mechanical characterization, Composites Part A: Applied Science and Manufacturing. 42, 649-657.

All © 2022 are reserved by International Journal of Advanced Science and Engineering. This Journal is licensed under a Creative Commons Attribution-Non Commercial-ShareAlike 3.0 Unported License.